NOAA SECTORAL APPLICATIONS RESEARCH PROGRAM (SARP)
PROJECT ANNUAL REPORT (DRAFT)

PROJECT TITLE
Climate-Informed Adaptive Management and Planning to Meet Urban Water Supply and Flood Mitigation Goals in the Delaware River Basin

INVESTIGATORS
(Research team and full contact information)
Gavin Gong, Columbia University, Department of Earth and Environmental Engineering*
Upmanu Lall, Columbia University, Department of Earth and Environmental Engineering
Casey Brown, International Research Institute for Climate and Society
Peter Kolesar, Columbia University, School of Business

* Department of Earth and Environmental Engineering
Columbia University, MC 4711
500 W. 120 Street, 918 Mudd Hall
New York, NY 10027
Tel. (212) 854-7287
Fax (212) 854-7081
Email gg2138@columbia.edu

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TIME PERIOD ADDRESSED BY REPORT *(e.g., August 2002-March 2003)*
August 2007 – April 2008

I. PRELIMINARY MATERIALS

The goal of this project is to incorporate climate and weather information into water resources management for the Delaware River Basin (DRB), in the context of the existing problems identified by DRB stakeholders. One problem is the lack of flexible operating rules that equitably meet the competing demands on the basin, which include federally mandated upstream diversions and instream flow rates for New York City water supply, flow and temperature requirements to meet conservation needs, and calls to use water supply reservoirs within the basin for flood mitigation. The other is the exclusion of climate variability and change considerations in the existing operating rules, which can have a substantial impact on the basin (e.g., recent floods and droughts), and can inform management decisions to better meet the aforementioned demands if known in advance.

We will work directly with collaborating DRB stakeholders to improve decision processes that will address these problems. To facilitate stakeholder engagement and implementation of results, our approach will be to build upon the management system that is already in place. By refining modeling and monitoring tools that are already used and trusted, the incorporation of climate and weather information will be more readily understood and therefore easier to accept. This is especially important given the probabilistic nature of climate forecasts and associated risks that must be communicated (e.g., if a climate forecast turns out to be inaccurate).

We propose to first develop a robust, probabilistic hydroclimatic forecasting and assessment capability for the DRB, then use it to design an effective, flexible and implementable adaptive Decision Support Tool for the DRB. These objectives will be achieved via a phased approach, in order to reconcile the short-term problem resolution needs within the DRB and the research application focus of the NOAA SARP element, with the research advancement needs that often arise when addressing complex, multi-user water resource management problems. The first phase will explicitly apply existing state-of-the-art climate-based forecasting techniques to the DRB, and refine the existing OASIS simulation system to explicitly incorporate this new information. The second phase consists of incremental improvements to the DST, through novel enhancements to hydroclimatic forecasting techniques and/or the DST, e.g. using Bayesian models and networks.

By providing an innovative yet familiar adaptive management system that can address competing demands by leveraging climate information, our results will benefit all DRB stakeholders, and by extension the societal interests represented by them. Our collaborating DRB stakeholders are amenable to this approach, and have expressed their written support for the proposed work.

A Project Abstract *(Limit to one page)*

The goal of this project is to incorporate climate and weather information into water resources management for the Delaware River Basin. A climate-informed adaptive management and planning strategy addresses both the multi-stakeholder and climatic non-stationarity problems, since dynamic (i.e., based on current and future climate) operating rules provide greater flexibility with which to support multiple interests. Achieving our goal entails two distinct but integrated objectives. The first objective is the development of a robust, probabilistic hydroclimatic forecasting and assessment capability for the DRB region, at nested timescales from daily to multi-annual/decadal. Resulting climate-based hydrologic scenarios will serve as input for our second objective, which is the design of an effective, robust and implementable adaptive Decision Support Tool for the DRB.

B Objective of Research Project *(Limit to one paragraph)*

Our methodological framework is divided into two phases, in order to reconcile the short-term problem resolution needs within the DRB and the research application focus of the NOAA SARP element, with the research advancement needs that often arise when addressing complex, multi-user water resource management problems. Phase I will apply current climate-based forecasting techniques to the DRB, and refine the existing OASIS simulation system to explicitly incorporate this new information. The focus is on application rather than enhancement, so as to introduce climate information into the current DRB system management in a timely, efficient and accessible manner. Phase II consists of a series of incremental improvements to methodologies applied in Phase I. System development plays a larger role, to overcome some of the limitations associated with current techniques. However, the incremental approach will allow us to maintain our focus on application and implementation of any new improvements. As the Decision Support Tool evolves it will retain its roots in the existing DRB management tools and thus remain accessible to all stakeholders.

We recognize at the outset that a stakeholder-driven approach relevant to specific questions is necessary to effectively introduce new climate information into the management of the DRB. Therefore, we have developed this proposal in the context of the existing water resources problems that are integral to the functioning of the DRB. Rather than seeking to educate decision makers about the role of climate information for some hypothetical application, or trying to engage a society-wide spectrum of users, we will work directly with DRB managers and stakeholders to improve decision processes, through the development of solutions to existing problems that utilize climate information.

To facilitate this direct and immediate engagement, our approach will be to build upon the management system that is already in place. By refining modeling tools that are already used and trusted by the various management entities, the incorporation of climate and weather information will be more readily understood and therefore easier to accept. This is especially important given the probabilistic nature of climate forecasts and associated risks that must be communicated (e.g., if a climate forecast turns out to be inaccurate). Furthermore, by starting within the current management framework, any limitations or weaknesses will be more apparent, so that more substantial modifications that may be required will be easier to implement. What will result is a viable, climate-informed, adaptively-managed decision support system for the DRB, which has its roots in an existing set of river basin simulation models that is frequently used and widely accepted by DRB managers and stakeholders.

To further expedite the application of our results into the actual decision-making process, we will focus initially on the upper-Delaware basin. Limiting the spatial domain in this way simplifies the physical system to be modeled considerably, so that climate-based impacts are easier to discern and interpret. Yet, the upper-Delaware includes the New York City water supply reservoirs, mandated streamflow criteria at Montague, NJ, and the fishery habitat that is of primary interest to conservation groups. Therefore many of the pressing problems facing the DRB can be effectively addressed by considering only its upper reaches.

C Approach (including methodological framework, models used, theory developed and tested, project monitoring and evaluation criteria) include a description of the key beneficiaries of the anticipated findings of this project (e.g., decision makers in a particular sector/level of government, researchers, private sector, science and resource management agencies) *(Limit to one page)*

D Description of any matching funds/activities used in this project *(Limit to one paragraph)*
None

II. ACCOMPLISHMENTS

A. Brief discussion of project timeline and tasks accomplished. Include a discussion of data collected, models developed or augmented, fieldwork undertaken, or analysis and/or evaluation undertaken, workshops held, training or other capacity building activities implemented. *(This can be submitted in bullet form – limit to two pages)*

This project was awarded in May 2008 and began in August 2008, which made it difficult to recruit a qualified graduate student in a timely manner. Meanwhile, a group of excellent undergraduate rising seniors had been working on associated projects in the DRB over the past 1-3 years. Therefore the decision was made to have these undergraduates work on Phase I of this project, in association with their Senior Design Project requirement. This strategy has proved effective, since the students' and combined academic strengths and familiarity with the DRB allowed them to start begin research tasks immediately and effectively. Furthermore, one of the undergraduates has enrolled in our graduate program, and will continue working on this project as he earns his masters degree, thereby ensuring continuity.

Probabilistic streamflow models have been developed for DRB reservoir inflows at two distinct timescales. Basic linear and logistic regression techniques have been applied to develop a springtime streamflow forecasting model based on preceding winter climate indicators, e.g. remote sea surface temperature, sea level pressure and zonal wind fields, and also local snow depths. Meanwhile, wavelet techniques were applied to develop a long-term stochastic timeseries simulation model for reservoir inflows, which captures low-frequency variability in order to evaluate the recurrence likelihood of extreme events, e.g. multi-year droughts.

The existing OASIS daily flow simulation model for the DRB system has been adapted to predict future system behavior in response to the seasonally forecasted system inflows, contingent upon reservoir levels at the time of the inflow forecast. Due to the probabilistic nature of the inflow forecasts and varying ambient reservoir levels at the time of forecast, OASIS modifications required extensive simulations of a broad suite of forecast response scenarios, from which system behavior can be readily predicted for a given year. Based on this predicted system behavior (e.g., extremely wet or dry), existing operational release policies are adjusted to optimize surplus water allocation or minimize water deficit risks.

B. Summary of findings, including their potential or actual implications for efforts to develop applications, methods, and science-based decision support capacity/systems and to foster sustainable resource management and vulnerability reduction. *(Limit to two pages)*

Basic linear and logistic regression techniques have yielded a seasonal forecast model with modest skill and lead-time. Consistent with the aims of Phase I of this project, results at this point demonstrate the potential for useful seasonal forecast applications, and also the need to apply more sophisticated techniques to improve forecast skill. The long-term streamflow simulations suggest that extreme drought akin to the mid-1960's event are statistically rare, hence the current, historically-based release policy is conservative. Once again though, refinements are ongoing to improve the reliability of these simulations.

Despite these current limitations, climate-informed release policy modifications have been developed using results thusfar. The modifications are based on existing modeling and decision support tools used by stakeholders within the DRB, namely the OASIS model and the current operational rule curves. As our climate simulation and forecasting skill improves during Phase II of this project, these improvements can be readily incorporated into policy modifications. By working within the existing operational setting, we have established a flexible framework for incrementally improving climate science-based decision support for DRB reservoir system management.

C. List of any reports, papers, publications or presentations arising from this project; please send any reprints of journal articles as they appear in the literature. Indicate whether a paper is formally reviewed and published. *(No text limit)*

Much of the work performed during this reporting period is documented in the attached Senior Design Project final report by the undergraduate students working of Phase I, for which each student received a grade of "A". A manuscript documenting our climate-based forecasting and simulation results using established techniques applied to the DRB region is currently being prepared for peer-reviewed publication submission.

D. Discussion of any significant deviations from proposed workplan (e.g., shift in priorities following consultation with program manager, delayed fieldwork due to late arrival of funds, obstacles encountered during the course of the project that have impacted outcome delivery). *(Limit to one paragraph)*

Feedback from stakeholders has thusfar occurred via informal discussion and presentations with individual stakeholders. Initially planned formal meetings involving all stakeholders were postponed until initial climate-based forecasts and simulations were developed, and a preliminary framework for release policy modification was established. These initial milestones are nearing completion, so a meeting of all stakeholders is being planned for summer 2008.

E. Where appropriate, describe the climate information products and forecasts considered in your project (both NOAA and non-NOAA); identify any specific feedback on the NOAA products that might be helpful for improvement. (bulleted response)

None.

III. GRAPHICS: PLEASE INCLUDE THE FOLLOWING GRAPHICS AS ATTACHMENTS TO YOUR REPORT

A. One Power point slide depicting the overall project framework/approach/results to date
B. If appropriate, additional graphic(s) or presentation(s) depicting any key research results thus far
C. Photographs (if easy to obtain) from fieldwork to depict study information (if applicable).

IV. WEBSITE ADDRESS FOR FURTHER INFORMATION (IF APPLICABLE)

V. ADDITIONAL RELEVANT INFORMATION NOT COVERED UNDER THE ABOVE CATEGORIES.